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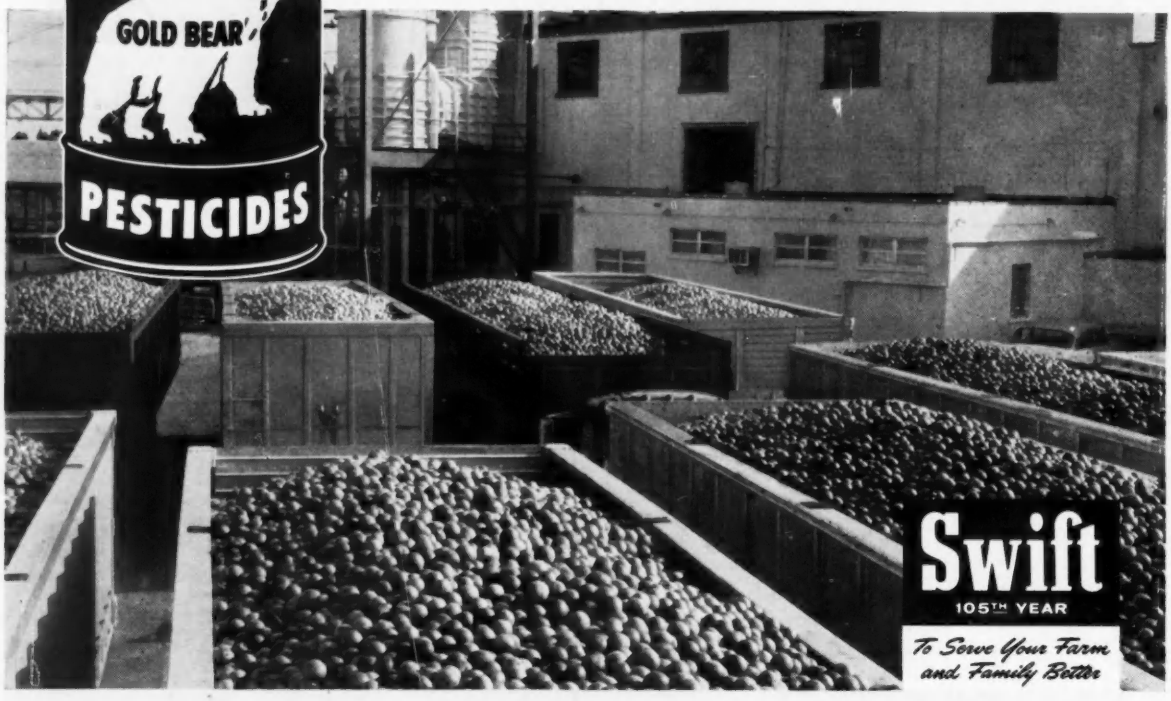

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Cold Hardiness In Citrus As Related To Dormancy

WILLIAM C. COOPER
Crops Research Division, Agricultural Research Service, USDA
Presented at Florida State Horticultural Society Meeting 1959

Introduction

Seldom do such pronounced changes in nature occur as after a sudden freeze in a citrus grove. Trees previously alive and healthy are a picture of destruction on the following day; leaves and young shoots are limp and blackened as though burned by fire. Trees better able than others to resist the freeze stand out because they show little or no injury. How can some trees be more cold-resistant than others from which they do not differ obviously?

The ability of some plants to withstand extremes of temperature, in contrast with the great sensitivity of others, is one of the oldest problems in plant science. Citriculturists and citrus breeders have been absorbed with this seeming paradox at one time or another for the past 65 years. Sometimes the problem was forgotten during a decade or so of warm winters, but it was quickly revived by the destruction in a "test" year such as 1951 in the Rio Grande Valley of Texas and 1957-58 in Florida.

Prior to 1951 the meager published information on cold hardiness of citrus was based on damage observed in experimental plantings that happened to exist at the time of freezes (4, 11, 12). While such observations are of value, the infrequent occurrence of "test winters"—only about one in every 10—does not permit sufficient readings for one to arrive at entirely sound conclusions. Earlier unpublished work by the author with detached leaves and twigs of citrus subjected to controlled freezing temperatures in small chambers at different times of the year was hard to interpret as it was not known whether the response of detached plant parts would reflect that of a tree in the field. In 1951 following the severe freeze of January 31 in the Rio Grande Valley of Texas, a portable tree freezer, consisting of a freezing compartment 5'x5'x5' on wheels, was constructed (Fig. 1). This equipment permitted exposure of a young tree in the field to controlled freezing temperatures and permitted the comparison of cold hardiness of trees in a specific physiological state (5).

Studies with this freezer showed that the cold hardiness of a tree is closely associated with the degree to which the tree exhibits winter dormancy (8). It was found that the dormancy of the tree involves the cessation of growth of cambium and roots as well as of shoots (8). A tree may show no visible bud growth and appear to be fully dormant, but investigation may show root-growth activity and bark slipping throughout the tree (8). Trees also show various degrees of bark slipping from a more or less tight dry bark to a bark that is easily peeled from the wood and so succulent that water actually drips from it (8).

The present paper presents some observations on the effects of air and soil temperatures on growth and dormancy of citrus in the Rio Grande Valley of Texas. The effect of various environmental factors and growth-regulating chemicals on control of dormancy is reviewed, with particular emphasis on results of experiments conducted in Texas in which the experimental trees with various degrees of dormancy were tested for cold hardiness. In these experiments the cold hardiness of the tree was measured by the number of degrees below the point of injury of the non-dormant tree to which the temperature of the tree must be lowered to produce injury. Any temperature below freezing (32°F) is to be considered dangerous if continued long enough. Ordinarily, under the conditions of the tests with the portable tree freezer, no great damage occurred to a non-dormant tree unless temperatures dropped to 27° and were maintained at that point or lower for several hours. Then only foliage and fruit on trees with new growth were injured. In California foliage on fully-dormant trees has frequently endured without injury temperatures of 20° for several hours (16). The present paper is concerned only with trees injured at temperatures between 27° and 20°, over which range we are concerned with the degree of dormancy of the tree. Thus, we are primarily measuring the effect of dormancy on cold hardiness.

Environmental conditions and growth-regulating chemicals applied to non-dormant trees may possibly also change physiological properties of the plant other than dormancy and thus affect cold hardiness. This must be accepted as a warning of the complexity of the problem. However, probably the main effect of these treatments in the tests described is on dormancy. To determine the true effects of these treatments on other physiological properties, fully-dormant trees should be used.

Seasonal Growth and Dormancy

Observations on growth presented in Table 1 represent both extension and radial growth of the top of the tree and general growth of the roots. Extension growth of new shoots was measured and these observations may be used as an index of bud dormancy; when no extension growth takes place, the buds are dormant. When extension growth is shown, the buds are elongating into shoots. The observations on radial growth represent increases in area of cross section of the twig, branch, and trunk This radial growth is used as an index of cambial activity. When no radial growth takes place, the cambium is assumed to be dormant. It was not feasible to obtain extension-growth measurements of roots, but by means of root observation boxes (14) it was possible to count white root tips at 2-week intervals. A white root tip indicates active growth; therefore the number of these white root tips is as an index of root growth.

The data presented in Table 1 represent the mean of 12 Shary red grapefruit trees on sour orange rootstock in an orchard owned by Rio Farms, Monte Alto, Texas. These trees were planted in 1950 and the measurements covered the period of June 1957 to May 1959. The orchard was under Bermuda grass sod from June until December 1957 and under clean cultivation for the remainder of the experiment. Air and soil temperatures, rainfall, and irrigation water supply to the grove also are shown in Table 1.

Similar data on 12-year-old Red Blush grapefruit trees in an orchard at Texas Agricultural Experiment Station, Weslaco, Texas were obtained. This practically duplicated data presented for the Rio Farms orchard in

Continued on page 5

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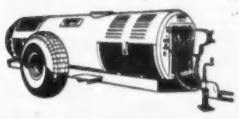

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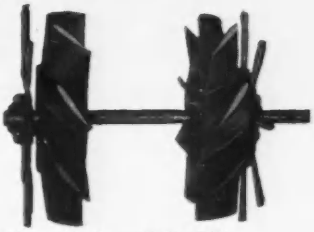

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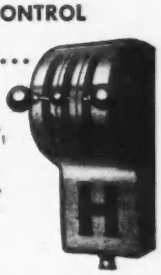

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Cold Hardiness In Citrus As Related To Dormancy

Continued from page 3

Table 1 and are not presented in this paper.

The data in Table 1 reveal that extension growth of shoots is intermittent with growth periods occurring in the early spring (February and March), late spring and early summer (May and June), and late summer and fall (August through October). Growth interruptions, or dormant periods, occurred in April, July, November, December and January. In contrast, radial growth of branches and twigs was continuous except for a brief period in the winter where some shrinkage occurred. Radial growth in the trunk was continuous but at a slower rate in the winter than at other times. Radial growth was slowed also during July, but it did not cease during the summer. The maximum period of radial growth occurred in August and September.

Root growth was also continuous. The minimum rate generally occurred in the winter, but in some instances the rate of root growth was low during July and August. The period of maximum root growth usually occurred in the fall

These results clearly indicate that in the Rio Grande Valley periods of bud dormancy occur in the spring and summer as well as in the winter, The winter period, however, is usually more prolonged than the spring and summer periods. Winter bud dormancy is usually accompanied by cambial dormancy in the twigs and branches but not in the trunk. Root growth also occurred, though at a slower rate during the winter. Therefore, it is concluded that trees under Rio Grande Valley conditions are not fully dormant during the winter.

The trees received adequate irrigation water or rainfall during the 2-year period of these observations, and none of the semi-dormant periods can be attributed to drought. The winter dormant periods, however, are associated with mean minimum air temperatures near 40°F. and mean minimum soil temperatures at 12 inches of 55° to 66°. The warmer environment surrounding the roots as compared with that of the tops of the trees probably accounts for the lack of dormancy in the roots as compared with the partial dormancy of the tops of the trees.

The influence of temperature on the growth of citrus is illustrated by the reactions of germinating seeds and young seedlings of various citrus species exposed to constant temperatures (1, 9, 13). The critical temperature for extension growth of shoots and roots of grapefruit is approximately 50°F (10). Thus, in all probability the prolonged winter dormancy of the buds of the grapefruit trees in the orchards described herein is caused by the 50° or below night air temperatures, while the continued growth of roots is permitted by the warm soil temperatures. In California, where winter night air temperatures are generally in the low 40°'s and soil temperatures are near 50°, roots, buds, and cambium are dormant and

Continued on page 10

Table 1. Seasonal growth and dormancy of Shary red grapefruit trees on sour orange rootstock at Monte Alto, Texas, as related to air and soil temperatures[1]

Year and Month	Air Temperature Mean Min.	Air Temperature Mean Max.	Soil Temperature[2] Mean Min.	Soil Temperature[2] Mean Max.	Rain + Irrigation	Extension growth of new shoots	Radial Growth[3] Trunk	Radial Growth[3] Branch	Radial Growth[3] Twig	Root growth (white root tips)
	°F	°F	°F	°F	in.	cm.	cm_2	mm_2	mm_2	No.
1957:										
June	69	91	81	82	2.7	5.0	4.3	39.4	2.28	28
July	73	96	84	84	4.0	0	1.3	21.0	.74	6
Aug.	73	100	82	85	5.0	10.0	1.8	21.9	2.50	3
Sept.	69	98	78	88	4.0	1.0	3.6	27.2	2.58	21
Oct.	60	91	68	82	4.2	5.0	3.9	29.8	2.13	208
Nov.	40	82	62	67	3.0	0	1.9	11.7	-1.20	274
Dec.	39	80	66	71	4.0	0	.4	- 1.8	- .12	154
1958:										
Jan.	40	80	56	62	12.0	0	1.2	- 1.5	.64	44
Feb.	42	80	62	67	0	9.6	1.4	9.8	.92	23
Mar.	45	86	66	70	.5	26.2	1.6	6.3	2.55	30
Apr.	55	92	72	78	4.0	0	3.6	33.1	2.73	49
May	66	93	80	82	1.7	21.2	4.2	35.5	2.33	52
June	74	95	82	84	6.7	8.8	3.7	34.4	5.11	50
July	70	93	84	88	6.9	0	2.7	18.2	3.58	86
Aug.	73	94	88	90	4.0	1.0	7.4	49.1	6.05	87
Sept.	75	92	81	89	9.5	1.0	8.1	52.3	5.50	122
Oct.	—	—	70	70	7.1	7.0	3.3	38.4	3.20	44
Nov.	57	82	73	74	1.9	0	2.5	18.8	.66	146
Dec.	39	80	66	66	1.1	0	.8	3.3	1.14	55
1959:										
Jan.	35	75	61	64	2.2	0	.8	- .4	.03	38
Feb.	43	80	56	65	0	5.2	.5	5.2	1.36	29
Mar.	47	87	65	68	4.0	45.1	1.2	7.1	1.72	17
Apr.	52	90	66	66	0	0	2.7	10.2	2.12	30
May	67	91	74	76	4.2	5.0	3.8	29.3	2.76	19

1—All growth data represents the mean value for 12 trees.
2—At 12-inch depth.
3—Increase in area of cross section since the last reading.

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1960 Florida Citrus Exposition In Winter Haven, Jan. 16-23

The theme of the 1960 Florida Citrus Exposition to be held in Winter Haven again this year, Jan. 16 through Jan. 23; will be built around this historical story of the growth and development of Florida's No. 1 agricultural industry. The story will run the gamuet of the antiquated hand operations of yesteryear down to the present day when space age techniques have far removed the production of Florida's great citrus crop for any semblance of its one-time laborous and primitive prodecdures.

The theme of this now multi-million dollar industry is referred to as the "inside story" of this extraordinary development, and artists and workmen are now putting the finishing touches on this 36th annual presentation of the industry.

The exposition dates were set to coincide with the National Canners Association convention to be held at the same time at Miami Beach. According to Ben Hill Griffin, Jr., president of the Exposition, in order to enable convention delegates to make a post-convention tour of the citrus belt and the Exposition on Jan. 21 and Jan. 22nd.

Included in this group will be citrus buyers, retailers, chain store executives and others who deal directly with the buying public, and who will be able to see the spectactular developments of the industry in the past few decades.

Highlights

Highlights of the coming Exposition will include the annual Citrus Queen contest with more than 20 Florida beauties competing for the title now held by Miss Sandra Freeman of Jacksonville. This competition will begin on Jan. 18 and will be climaxed at the annual Coronation ball to be held the evening of Jan. 20.

On Jan. 21 the NCA group and processors from all over the state of Florida will gather for the Canners Day luncheon and on the following day leaders representing all phases of Florida's agrarian economy will be in Winter Haven to attend the Agricultural Day luncheon. Nationally known authorities are to be featured speakers at both these events which will be held in Mayo Hall.

On Friday afternoon Jan. 22 more than 2000 persons are expected to attend the annual Fruitman's Dinner which will be held that afternoon.

The Annual featured Press Breakfast is scheduled to be held on that same night, with representatives of the press, TV and radio from every section of Florida.

Each day's activities at the Exposition will be climaxed nightly, with a gigantic display of fireworks on the shores of Lake Silver.

Schools Closed

The big annual Florida Citrus Exposition parade will be held on Monday, Jan. 18 at 9:30 in the morning. Schools in Polk county will be closed for the day and it is expected that some 40,000 students are expected to join adult members of their families in seeing the parade and in participating in other entertainment features of the Exposition.

"On The Go" Show

The 1960 Florida Citrus Exposition also gets an added publicity break from Jan. 18-22 before a nation-wide television audience of nine million persons.

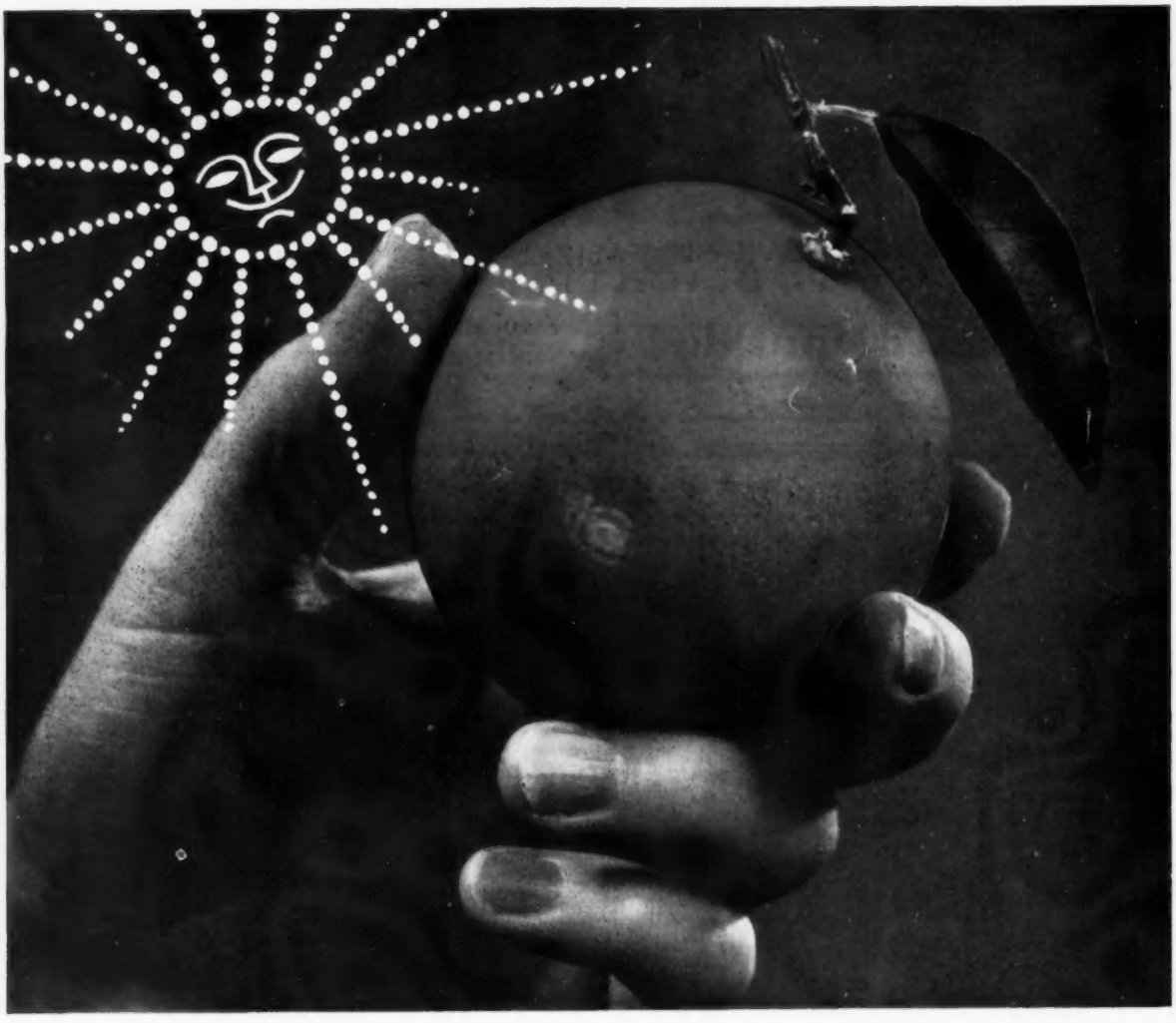
With the aid of the Florida Citrus Commission, the Columbia Broadcasting System will originate its daily "On The Go" show from the heart of the citrus belt. The additional costs of video-taping the show in Florida, estimated at about $40,000, will be paid by the Florida Citrus Commission.

"On The Go," narrated by Jack Linkletter, son of Art Linkletter, also will tape shows at Cypress Gardens and one at the Boca Raton Club.

The invitation to the NCA group to tour the citrus belt brought out a new type of programming by the Florida Citrus Exposition.

Under the direction of John A. Snively, Jr., the entertainment com-

Continued on page 28



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Cold Hardiness In Citrus As Related To Dormancy

Continued from page 6

tle trees may be considered as fully dormant.

Effect of Drought On Dormany and Cold Hardiness

The more or less inactive cambium in the grapefrut trees described previously is typical of that of 88- to 12-year-old trees in the area. In all parts of younger trees, however, the cambium usually remains active all winter if adequate soil moisture is provided even though the buds are dormant (8). Results by Cooper (8) (reproduced in Table 2)) show that buds of 3-year-old Red Blush grapefruit trees irrigated on December 4 remain dormant during all all of December and the first half of January. They began to break during the third week in January and shoot elongation took place in late January and early February. Cambial activity (as indicated by bark slipping) in the trunk remained at a high level all winter. The bark in the twigs and large limbs peeled slightly less readily during December and early January, but at no time did the bark fail to peel readily except on occasional limbs on several trees. In early February following the flush of bud growth, the bark on the twigs and large limbs peeled very readily and was visibly succulent

Further experiments by Cooper (8) show that until mid-January bud growth and bark peeling of grapefruit and Meyer lemon trees not irrigated on December 4 followed the pattern described for the irrigated grapefruit trees. During the next 3 weeks the buds remained dormant, and cambial activity in all parts of the trees decreased instead of increasing as in irrigated trees. On February 7 the bark of the Meyer lemon trees failed to peel and appeared completely dormant, while that of the grapefruit trees peeled with difficulty. Thus, withholding irrigation water during this particular winter period caused a low level of cambial activity in the top of the tree during late January and early February.

The cold hardiness of these trees was not tested in the portable tree freezer until early January. At this time the minimum temperatures causing injury to both irrigated and non-irrigated grapefruit trees was 23°F. If 27° is used as the base value for the injury point of a non-dormant tree, these partially-dormant grapefruit trees in early January had 4 degrees of cold hardiness. In early February following the flush of bud growth and increase in cambial activity in the top of the tree, the minimum temperature inducing incipient injury to irrigated grapefruit trees in the tree freezer was 27°; thus such trees lost their cold hardiness. At the same time the minimum temperature inducing incipient injury to non-irrigated trees was still 23° for grapefruit but had dropped to 20.5° for Meyer lemon. Thus, during January there was no change in the cold hardiness of non-irrigated grapefruit trees, but there was an increase of 2½ degrees in the cold hardiness of the Meyer lemon. This greater cold hardiness of the Meyer lemon than of the grapefruit was associated with a less active cambium in the former than in the latter. The bark on the trunk of the Meyer lemon became tight and could not be peeled, while that on the grapefruit could be separated from the wood.

On February 12, three of the Meyer lemon trees were irrigated. One week later buds were beginning

Continued on page 27

Table 2. Bud growth and bark slipping in large limbs and twigs of 3-year-old Red Blush grapefruit trees on sour orange rootstock during December, January and part of February. (Adapted from Cooper, et al (8))

Date of observation	Bud-growth score (0 to 5)[1]	Bark-slipping score (0 to 5)[2]
Dec. 1	0	5
Jan. 1	0	2
Jan. 15	0	2
Jan. 21	1	2
Feb. 1	3	-
Feb. 7	5	5

1—0, buds dormant; 1, buds just breaking; 3, buds ½ inch long; 5, buds 2 or more inches long.
2—0, bark tight; 2, bark barely peels; 5, bark peels easily and is succulent.

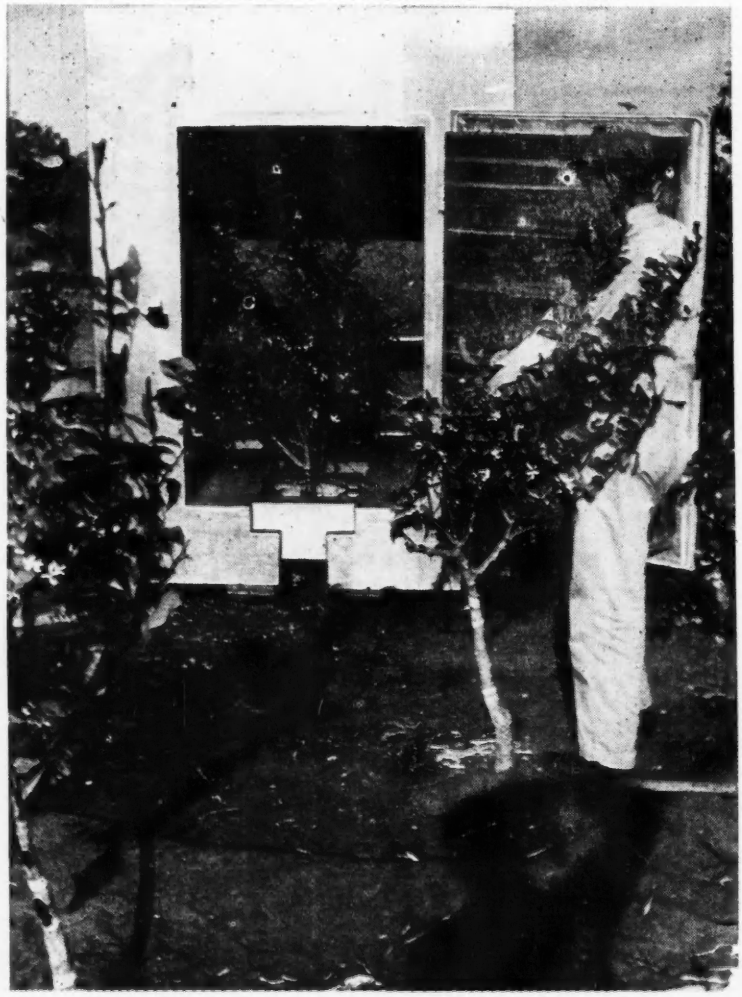

Figure 1. The portable tree freezer in place over a 3-year-old grapefruit tree. The door of the freezer is open to expose the tree to view.

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Seasonal Changes In Florida Tangelos

By PAUL L. HARDING, principal plant pathologist, MILLIARD B. SUNDAY, biological science technician, and PAUL L. DAVIS, chemist, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service

Seasonal changes and yearly variations for the principal commercial varieties of tangelos (Citrus reticulata X C. paradisi) are presented. The varieties included are Orlando, Thornton, Minneola, and Seminole. Chemical constituents and physical characteristics were determined and the data correlated with palatability tests.

These tests provided a basis for the establishment of standards of maturity at harvest for these varieties of tangelos. The test period was from October to February for the four crop years 1952-53 to 1955-56. The groves were chosen to represent typical plantings in Florida. The rootstocks included sour orange (Citrus Aurantium), Cleopatra tangerine (C. reticulata), rough lemon (C. Limon), sweet orange (C. sinensis), Rusk citrange (Poncirus trifoliata X C. sinensis), and sweet lemon (C. Limon).

The Orlando reached maturity first and Seminole last; Thornton and Minneola were intermediate. To insure good eating quality, a marketing standard was established having varying requirements through the season. A nomograph was devised for easy calculation of minimum market acceptability. This standard provides for a sliding scale of acceptability based on seasonal changes in solids and acids and in the solids-to-acids ratio.

Early season fruit must have a minimum of 9 percent total solids and a minimum ratio of solids to acid of 10 to 1. As the season progresses the minimum total solids requirement decreases and the minimum total solids to total acid ratio increases. The quality and quantity of fruit reaching the consumer can easily be controlled by adjustment of this standard.

The weight of total soluble solids increased and the weight of total acid decreased during the marketing season. These factors, together with the resulting solids-to-acid ratio, were closely associated with the palatability ratings.

Ascorbic acid (vitamin C) concentration showed no marked tendency to fluctuate during the season. Active acidity gradually decreased as the tangelos ripened.

Both the volume of juice and weight of the fruit increased during maturation and tended to level off or decrease slightly after prime eating quality was reached.

Degreening was associated with maturation and took place rapidly during the October to February period.

By the time the fruit reached the minimum standard of consumer acceptability the color of the flesh was yellow-orange to orange for Orlando, Minneola, and Seminole tangelos, and tannish yellow for Thornton. Flesh texture of all varieties was good at this time.

Variation associated with rootstock was not as pronounced as that associated with variety. For Orlando tangelos, total solids, total acid, and palatability ratings were higher in fruit from trees on Cleopatra rootstock than in fruit from trees on some of the others, such as rough lemon.

Yearly variations in fruit characteristics were associated with rainfall. Fruits produced during a relatively wet season were heavy and had a high volume of juice; the juice had low total solids and total acid. During a relatively dry season the fruits were relatively light and had a low volume of juice. However, the total solids, total acid, and solids-to-acid ratio were high.

The Orlando, Minneola, and Seminole tangelos resemble the tangerine parent in many respects, such as total solids content, ascorbic acid concentration, active acidity, and rind color. The Thornton tangelo resembles the grapefruit parent in total solids content, ascorbic acid concentration, and color of the rind.

Introduction

Tangelos (Citrus reticula X C. paradisi) are grown in Florida and marketed as specialty fruits. They are important items in the gift box trade which comprises about three million pieces, but in recent years commercial marketing of tangelos on the carlot basis has become even more important. Within 29 years, 1928 to 1957, nearly 400,000 tangelo trees, enough for planting over 5,000 acres, were reported to the Florida State Plant Board inspector as having been moved from Florida nurseries to Florida destinations (14). During the 1957-58 season, about 250,000 packed 4/5- bushel boxes of tangelos were certified by the Florida Inspection Service (6).

Tangelos comprise a group of citrus fruits which are hybrids of the tangerine, or mandarin orange (Citrus or pummelo (C. paradisi and C. reticulata), with either the grapefruit, grandis) (21). The tangelos used in this investigation, however, were crosses of Citrus reticulata X C. paradisi.

The name tangelo is a combination of the first syllable of tangerine and the last three letters of pummelo. The first crosses giving rise to this group of fruits were made by Swingle at Eustis, Fla., in 1897. Other crosses were made by Webber in 1898. Another series of crosses by Swingle, Robinson, and Savage (17) cover a period from 1908 to 1912. This plant breeding work was done principally at Eustis and Glen St. Mary, Fla., by scientists of the U.S. Department of Agriculture.

In this investigation the fruit development and compositional changes of the principal varieties of tangelos were studied during marketing seasons 1952-53 to 1955-56. From the results, it has been possible to establish minimum maturity standards by correlating physical measurements and chemical constituents with palatability ratings of the fruit. Practical standards were set up on a sliding scale. For example, early in the season a minimum of 9 percent total solids and a minimum solids-to-acid ratio of 10 to 1 is required, while for late season fruit the requirements are a minimum of 8 percent total solids and a minimum solids-to-acid ratio of 10.50 to 1.

This study is a part of a broad program of research aimed at improving market efficiency, and expanding markets for farm products.

Description of Orlando, Thornton, Minneola, and Seminole Tangelos And Their Rootstocks

Tangelo varieties vary widely in tree and fruit characteristics. The trees are vigorous, usually attaining standard orange tree size. However, it is mainly the fruit characteristics that interest the grower, shipper, and consumer. The different kinds of tangelo fruits vary considerably in size, shape, color of rind and flesh, flavor,

and date of maturation. Webber (21) points out that in general, tangelo trees produce fruits about the size of the common sweet orange.

The fruits exhibit a tendency to be slightly drawn out at the stem end or necked. Tangelo fruits are usually highy colored—the Orlando, Minneola, and Seminole, bright orange; Thornton, bright yellow. They are aromatic, richly flavored, sprightly acid, only slightly bitter, and very juicy. The rind is usually smooth or slightly bumpy, thin, comparatively loose and easily removable like that of the tangerine.

The Orlando tangelo (formerly known as "Lake") is the result of the cross, Bowen grapefruit X Dancy tangerine, with the latter as the pollen parent (17, 18, 21). Orlando is one of the earliest maturing tangelos and harvesting usually begins in early November. However, prime eating quality is not reached until January. The fruit is attractive, highly colored, deep orange to almost tangerine red, and has a thin rind, which is slightly pebbly but not rough. They are about the size of tangerines, the average diameter being from 2-5/16 to 3-2/16 inches. The fruit is slightly flat and contains 10 to 12 seeds.

The Thornton tangelo is believed to be a result of crosses between tangerine and grapefruit (16, 17). It dates back to crosses made by Swingle and Webber in 1897-98 at Eustis, Fla. Swingle, Robinson, and Savage state that "the original records of the group of hybrids giving rise to the Thornton tangelo were lost, so that the pollen parent is not definitely known. As many of the sister hybrids show unmistakable tangerine characteristics, however, it is safe to say that this fruit is a tangelo with grapefruit the known seed parent" (17).

The fruit attain prime eating quality in January and February, although harvesting begins in December. The Thornton is unusual in appearance in that the rind is soft and thick, somewhat wrinkled and pebbly, and the color of the rind and flesh is yellow orange. The fruits range in size from about 2-8/16 to 3-2/16 inches and are flattened at the blossom end and slightly tapered at the stem end. Seeds range in number from 10 to 25 per fruit.

The Minneola tangelo is the result of a cross in which the Bowen grapefruit was pollinated with pollen from the Dancy tangerine (17,21). The fruit reaches prime eating quality in January and February, although harvesting begins in December. The Minneola is probably the most attractive of the tangelos, and when fully ripe the color of the rind is deep reddish orange. The fruits are medium large in size and range from 2-5/16 to 3-6/16 inches in diameter or larger. They are somewhat flattened at the blossom end, and the stem end of the fruit is slightly raised but does not form a distinct nipple. The fruit contains 7 to 12 small seeds closely grouped at the center.

The Seminole tangelo, like the Orlando and Minneola, is a result of crosses between Bowen grapefruit with pollen from the Dancy tangerine (17, 21). The fruit reaches prime eating quality in February or March, although harvesting begins in January. This is one of the most attractive of the tangelo fruits, and in general appearance is more like a highly colored orange. Fruit size averages from about 2-8/16 to 3-2/16 inches in diameter. The rind is thin, smooth, and glossy with a tendency to crease. Seeds are numerous, 20 or more, short, plump, and closely grouped at the center. The flavor of the juice is tart and sprightly which accounts for the late marketability.

Tangelos have been grown chiefly on sour orange (Citrus Aurantium) rootstock. However, because of the susceptibility of sour orange to the virus disease tristeza, this rootstock is losing favor. In recent years there

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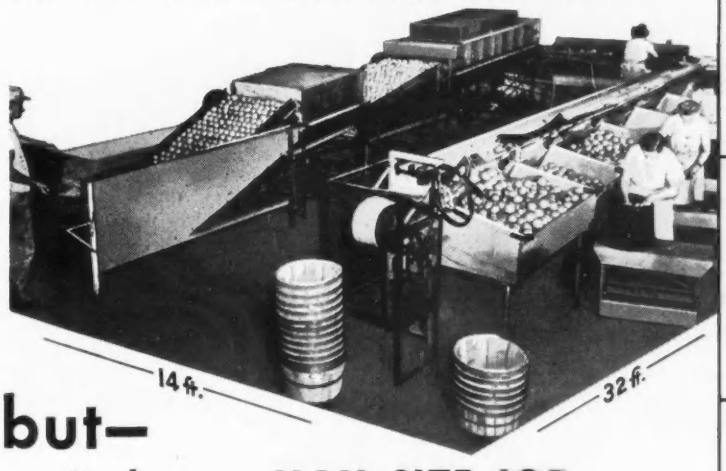

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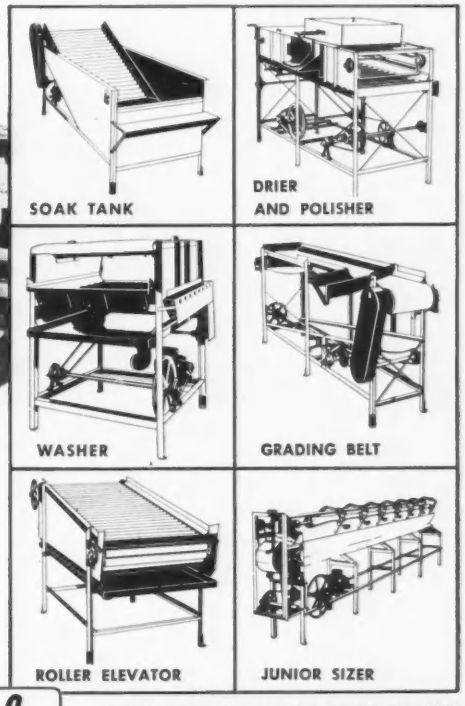

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has been fairly large-scale planting of tangelos on rootstocks of Cleopatra tangerine (C. reticulata, referred to hereafter as Cleopatra), rough lemon (C. Limon), and sweet orange (C. sinensis). Rusk Citrange (Poncirus trifoliata X Citrus sinensis, referred to hereafter as Rusk) rootstock is also used in a limited way in Florida.

During the 5 months, October through February, marked physical and chemical changes occur in the fruit. Tangelos, like oranges and grapefruit, do not improve in palatability after harvest. Since they contain practically no starch, they do not undergo marked changes in composition after being picked from the tree, as do apples, pears, mangos, and bananas.

The degree of maturity of tangelos at the time of harvest is the most important factor determining their eating quality. They owe their sweetness to natural sugars contained when they are picked and it can readily be understood that they should not be harvested until they are ripe. It is recognized that other factors, such as weather conditions, soils, fertilizers, cultivation, spraying, and dusting, may also affect eating quality. Some observations regarding the effect of rainfall were made in connection with this investigation.

Materials and Methods

Selection of Plots and Samples

The varieties studied were the commercially important ones—Orlando, Thornton, Minneola, and Seminole. The commercial groves used for fruit sampling were selected to represent average tangelo plantings in Florida. They were located in the central and ridge districts on sandy soils relatively low in organic matter, and in the west coast Bradenton-Terra Ceia districts where the soils have a relatively higher organic matter content.

In each of these districts the tangelos in the plots were on the following rootstocks. Six different groves of Orlando tangelos were on rough lemon, 10 on sour orange, 4 on Cleopatra, 3 on Rusk, and 1 on sweet lemon. Three different groves of Thornton tangelos were on rough lemon, and three on Cleopatra. Two different groves of Minneola tangelos were on rough lemon, three on sour orange, two on Cleopatra, and one on sweet orange. Three different Seminole tangelo groves were on sour orange and one on Cleopatra.

The sample groves ranged in age from 5 to approximately 25 years. Most of them were mature but none were considered old for citrus trees. All the groves were in good condition and had received normal culture, fertilizer, and spray treatments. The trees showed no evidence of deficiency disorders.

The tests were started the first week in October and continued until January or February, at which time some of the fruit was showing signs of senescence as indicated by creasing, puffiness, separation of the flesh from the rind, drying out of segments, and dropping from the trees.

Samples consisting of at least 125 fruits were picked from each plot at intervals of about 4 weeks. Care was taken to pick fruits from only the regular bloom and the fruits were selected to be representative of various parts of the trees since some of the chemical constituents vary with location of the fruit on the tree (11, 15). Immediately after being picked the samples were taken to the U.S. Department of Agriculture Horticultural Field Station at Orlando, Fla., and placed in storage at 32° F. They were tested as promptly thereafter as was feasible. The samplings continued through four marketing seasons 1952-53 to 1955-56, a period within which considerable variation occurred in weather conditions and fruit quality.

Evaluating Palatability

As pointed out in a recent symposium (1) flavor is highly complex and usually involves more than the major flavor constituent. The complexity of flavor is shown by the fact that analysis of volatile odorous substances in the strawberry has led to the isolation of about 35 substances; however, it is still not possible to reconstitute a really fresh strawberry flavor. The characteristic aroma of citrus is ascribed to high-boiling, sparingly water-soluble oils. Unlike the plant lipids, which are esters of long-chain fatty acids, these oils are mainly mixtures of terpenes, such as d-limonene.

Special attention was given to the eating quality of the fruit, since the taste ratings were to be compared with certain chemical constituents. Taste appeal is determined by the texture of the flesh, juiciness, contents of total solids and total acid, the ratio of total solids to total acid, frequently referred to as the solids-to-acid ratio, and a host of trace components which go to make up "flavor."

In each taste test about 100 tangelos were used. The fruits were halved crosswise, and from each half two wedge-shaped pieces were cut for testing. Each judge was instructed to taste several pieces before rating the lot. Judges did not discuss their ratings with each other. Each judge individually appraised each lot of fruit and gave it a numerical rating, and the ratings of all judges were averaged. Tasters were not restricted to any numerical range in rating insipid or aged fruit.

Chemical Analysis

Juice of 25 fruits from the samples rated for palatability was composited for chemical analysis. The juice was extracted by a pressure extractor (12) and strained to remove seeds and pulp. Chemical analyses continued through the 4 seasons for 21 plots, through 3 seasons for 13 plots, through 2 seasons for 3 plots, and through 1 season for 5 plots.

The analyses included determinations of total solids (principally sugars), total acid (as citric), ascorbic acid (vitamin C), and active acidity (pH). Standard methods were followed (2, 4, 7).

Evaluating Physical Characters

The appearance or "eye appeal" cannot be overlooked in general marketability, even though it may not always be correlated with taste. In this, as in other studies on citrus fruits (8, 9, 10, 12) considerable attention was given to the mesauring of physical characteristics each time the fruit was rated for palatability. The measurements of these characteristics were averaged to determine the correlation between the appearance and physical qualities and the results of chemical analyses and palatability tests.

Certain characters, such as weight, volume of juice, and weight of juice are readily measured and averaged. Other characteristics, such as color and texture were determined as described herein.

Color of Rind.—The "average" color for each sample was ascertained by assigning a numerical value to each color, averaging these values, and then converting each numerical average to the nearest color designation.

Color of Flesh—Color of the flesh of tangelos was determined by matching the halves of 25 transversely cut fruit with the color charts of the Maerz and Paul Dictionary of Color (13). Because the color graduations were many, these colors were grouped in five classes: PY, pale yellow; TY, tannish yellow; OY, orange yellow; YO, yellow orange; O, orange. Typical color for a sample lot was determined by the procedure given in the previous paragraph.

Condition of Flesh.—The texture of the flesh was determined for each sample after the fruits were halved transversely. Classification was based on the percentage of tangelos in each sample that were of coarse texture, good texture, and overmature. Fruit in which the vesicle cell walls were

Continued on page 16

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thick and conspicuous and the juice vesicles not distended with juice was designated as coarse; that fruit in which the vesicle cell walls were thin and inconspicuous and the juice vesicles fully expanded was designated as good-textured; and that fruit in which the flesh had separated from a part or most of the rind, or where there was a separation of the segments, or granulation or drying-out of the flesh, was designated as overmature.

Results

Values obtained for Orlando, Thornton, Minneola, and Seminole tangelos by averaging original data for the plots studied. Values representing the 4-year averages were arithmetic averages of the total plots for the four crop years and were weighted according to the number of plots observed per year.

Relationship of Physical and Chemical Factors to Palatability

Quality of citrus fruits affects prices, sales, and the consumer's decision to buy or not to buy a particular product. With this in mind, considerable study was given to the correlation of results of taste tests with chemical analyses and physical characteristics.

Palatability as measured by taste test panels generally increased rapidly as fruit matured, and was correlated with increases in total solids and total solids to total acid ratio, color of rind, weight of fruit, volume of juice, and pH values. The Orlando reached maturity first and Seminole last; Thornton and Minneola were intermediate. At prime condition, the Orlando and Minneola tangelos rated higher in palatability than the Thorntons and Seminoles.

Although it is recognized that many factors influence fruit quality and acceptability to the consumer, a reliable index of acceptability has been found in the relation of the total solids to the total acid (the total solids to the total acid ratio) of the juice.

Nomographs similar to those previously made for Temple oranges (10), tangerines (9), and grapefruit (8), showing the relation of consumer approval to total solids and total acid were constructed for each variety of tangelo. These were obtained by connecting lines between values for total solids and total acid for each of the samples which rated 70 or more in the taste tests. From the nomographs thus drawn, base lines of minimum acceptability were established.

These standards were enacted by the Legislature of the State of Florida in 1957 at the request of the citrus industry (5). Should the consumer demand sweeter fruit, the standards could be easily adjusted by an increase in ratio requirements, or an increase in minimum solids, or both. Conversely, in order to allow more tart fruit to be shipped, the ratio requirements could be decreased, the minimum solids requirement decreased, or both.

The relationship between total solids, total acid, solids-to-acid ratio, and palatability of the 398 samples rated as acceptable and used in construction of the nomograph. From this it can be seen that over 60 percent of the fruit had total solids ranging from 10.00 to 11.99 percent, total acid from 0.38 to 1.42 percent, and ratios from 7.80 to 29.29. Over 80 percent of the samples had total solids between 9.17 and 11.99 percent with the same ranges as above for total acid and ratios.

Of a total of 585 samples tested, 187 samples failed to pass the test for consumer approval. Low palatability ratings were usually associated with low total solids content, high total acid content, and, in some cases, lack of juiciness and coarse texture of the flesh.

Total Solids, Total Acid, and Solids-to-Acid Ratios

The balance between total solids, which are principally sugars in mature fruit, and total acid, is closely related to palatability. As with tangerines (9), the Orlando, Minneola, and Seminole tangelos increaed in total solids rapidly and reached high levels of total solids. Thornton tangelos resembled grapefruit (8), in that they increased slowly in total solids content from an average of about 9 percent in October to about 10.5 percent in February.

At the level of minimum acceptability the total solids were 9.8 percent for Orlando and Thornton tangelos, 11.0 percent for Minneolas, and 11.2 percent for Seminoles. Orlando, Thornton, and Minneola tangelos grown on Cleopatra rootstock were consistently higher in total solids than when grown on rough lemon rootstock.

Total acid decreased during the season, this decrease being fairly rapid up to maturity, and very slow thereafter.

There were consistent varietal differences in total acid content. At minimum acceptability, Orlando tangelos averaged 0.93, Thorntons 0.93, Minneolas 1.26, and Seminoles 1.38 percent acid, when all were grown on Cleopatra rootstock.

Orlando tangelos grown on Cleopatra, sour orange, and Rusk rootstock had a slightly higher total acid than those grown on rough lemon. The effect of rootstock on total acid was more variable for Minneola and Seminole tangelos.

The ratio of weight of total solids to weight of total acid gives an indication both of maturity and consumer acceptability, and is a part of the Florida laws. At minimum maturity, Orlando, Thornton, Minneola, and Seminole tangelos on Cleopatra rootstock had high solids-to-acid ratios, 10.20, 10.50, 9.90, and 8.10, respectively. The low ratio for Seminole was due primarily to the high acid content of this variety.

The kind of rootstock had little effect on the solids-to-acid ratio for Orlando, Thornton, or Seminole varieties. Minneola tangelos, in February, showed wider variation according to rootstock, with a low of 12.73 on rough lemon and a high of 18.49 on sweet orange.

Ascorbic Acid

The ascorbic acid content of the principal varieties of tangelos was about equal to that of the tangerine parent (9), and slightly lower than that normally found in the grapefruit parent (8). The concentration of ascorbic acid of the juice reaches a maximum in the early stages of development and remains fairly constant during the marketing season.

Of the different varieties on Cleopatra rootstock, Thornton tangelos had the highest average ascorbic acid concentration, and Minneola the lowest. Orlando and Seminole fruits were intermediate.

The ascorbic acid concentration varied less with rootstock than with variety, although Orlando tangelos on sour orange and Cleopatra rootstock averaged slightly higher in ascorbic acid than those on rough lemon or Rusk.

Active Acidity

In active acidity, the tangelos resemble the tangerine parent (9), rather than the grapefruit (8). In October, when all varieties of fruit are immature, the pH values ranged from as low as 2.8 in Seminoles to 3.2 in Orlandos. By February, the pH values had increased, ranging from 3.3 in Seminoles to 3.9 in Orlando tangelos. Thus the active acidity, a measure of hydrogen ion concentration, decreased (pH values increased) steadily during the development of the fruit. It should be borne in mind that since pH units are logarithmic values, a change of one pH unit represents a tenfold change.

Weight of Fruit and Juice per Fruit

The changes in weight of fruit

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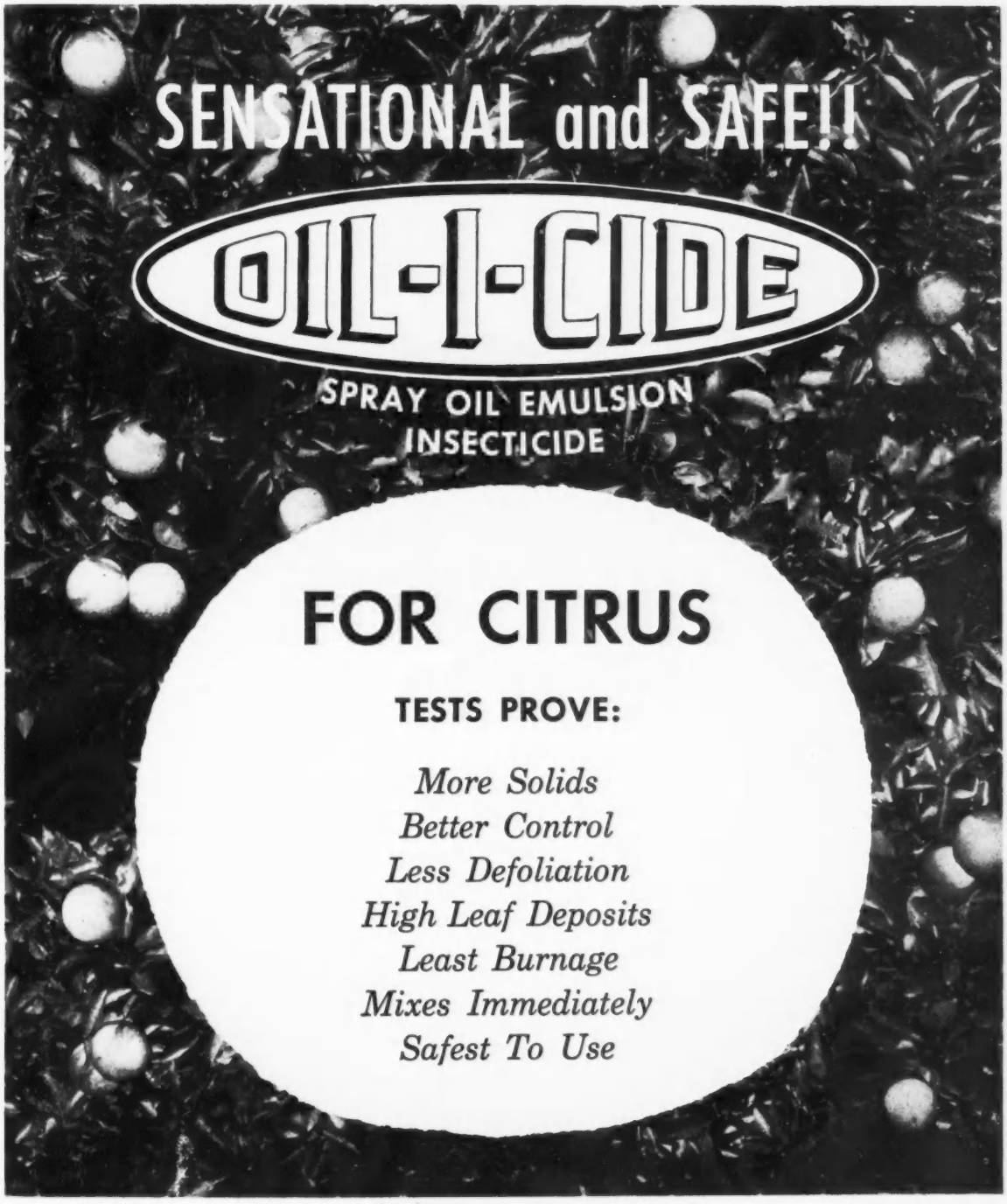

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Seasonal Changes In Florida Tangelos

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closely paralleled the increase in volume of juice per fruit. The average weight of fruit increased until maturity was reached. Thornton, Minneola, and Seminole tangelos showed greater rates of increase than the Orlando. Rootstock had only a very slight effect on weight of fruit.

During early stages of development the volume of juice increased rapidly, reached a maximum when the fruit was in prime condition, and decreased slowly as the fruit remained on the tree. The volume of juice per fruit was associated with variety. Minneola tangelos were the largest in size and averaged about 200 milliliters of juice per fruit. Seminole and Thornton tangelos were intermediate as to size and volume of juice. Orlando tangelos were smaller and contained a lower amount of juice.

The percentage of fruit by weight that was juice and the milliliters of juice per 100 grams of fruit decreased very slightly throughout the season. Variety and rootstock had little influence on the amount of juice per fruit, and during the period of prime eating quality the juice averaged from about 58 to 61 percent of the fruit.

Rind Color

Rind color was determined by matching samples of 25 fruit against the color standards. In October the tangelos were deep yellow-green in color. As the fruit matured the green pigment faded rather rapidly. The rinds of Minneola, Orlando, and Seminole tangelos progressed through yellow to yellow-orange and finally became deep red-orange in color. Of these varieties, Minneola had the deepest color. Thorntons remained yellow to yellow-orange at maturity and resembled the grapefruit parent rather than the tangerine.

Natural degreening, associated with maturation of the fruit, progressed very rapidly during the 3 months October through December. It has been found by Bain (3) that the period of maturation is distinguished by a change in rind color accompanied by decreased rates of morphological, anatomical, and physiological changes.

Color and Texture of Flesh

The flesh of the Orlando and Minneola tangelos was yellow-orange in October, became orange by November and remained so during the November to February period. Seminole tangelos changed from orange-yellow to yellow orange to orange at about minimum maturity. Thornton tangelos retained a tannish-yellow color throughout the harvesting season. The different rootstocks had no apparent effect on color or texture of the flesh.

In October the flesh texture of Orlando, Thornton, Minneola, and Seminole tangelos was classified as "coarse." As each variety reached the stage of consumer acceptability, the texture became "good."

Influence of Kind of Rootstock on Fruit Quality

Slight differences in total solids, total acid, ascorbic acid, and palatability were associated with kind of rootstock. There was very little difference in weight of fruit, rind color, active acidity, or color or condition of flesh attributable to kind of rootstock.

The effect of rootstock on fruit characteristics of young Orlando variety trees is shown in data presented. These trees were 5 years of age and were grown under similar cultural conditions. Fruit from trees on Cleopatra rootstock had significantly higher total solids, total acid, and palatability ratings than fruit from trees on rough lemon or sweet lemon. The weight of the fruit and volume of juice were not influenced by kind of rootstock. These findings on young trees were in general agreement with the averages of all trees.

Yearly Variations in Chemical and Physical Factors

Yearly variations in chemical and physical factors are illustrated by a comparison of Orlando tangelos on rough lemon, sour orange, and Cleopatra rootstocks. In the four year period the greatest differences were noted between the 1953-54 and the 1955-56 crop years. During the 1953-54 season the weight of fruit, volume of juice, and pH values were high, and total solids, total acid, and ascorbic acid concentration were low. The low acid content resulted in a high solids-to-acid ratio early in the season and is reflected in consumer acceptance of early harvested fruit, according to palatability tests for that year. On the other hand, in crop year 1955-56, the weight of fruit and volume of juice were low, and total solids, total acid, and solids-to-acid ratio were high. Palatability, however, was not appreciably different from the 1952-53 and 1954-55 crop years.

Undoubtedly variations in yearly rainfall influenced these factors. The year 1953 was the second wettest since 1891 with a Statewide average of almost 15 inches above normal (19). The precipitation in 1955 totaled only a little over 42 inches and was about 80 percent of average expectancy (20). As previously pointed out, sunshine, soils, fertilizers, cultivation, spraying, and dusting may also have affected these factors.

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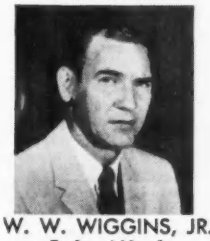

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Breeding Citrus For Cold Hardiness

J. R. FURR and W. W. ARMSTRONG, JR., Crops Research Division
Agricultural Research Service; U.S.D.A. Paper presented at
Florida State Horticultural Society Meeting 1959

The possibility of severe loss from cold injury is an ever-present hazard for the citrus grower in all of the major citrus-growing regions of this country. The severe freezes of 1949 and 1951 in Texas, the equally severe, but less damaging, ones in California and Arizona in 1949 and 1950, and the freezes of 1957-58 in Florida have stimulated renewed interest in research work on cold hardiness of citrus. In recognition of this need, the horticultural laboratories of the United States Department of Agriculture at Orlando, Florida; Weslaco, Texas; and Indio, California, were recently provided funds for increasing work related to cold hardiness of citrus. At these three laboratories investigations are being planned, or are already under way, with the ultimate object of reducing losses from cold injury to citrus.

One of the most obvious methods of reducing losses from frost is the production by breeding and selection of cold-hardy varieties. Citrus breeding was begun in this country in 1893 by Webber and Swingle (7) just before the disastrous freezes of 1894-95 in Florida, and most of the hybrids produced were lost in the freeze. Consequently, when this work was renewed in 1896, one of the primary objectives was the production of cold-hardy varieties.

In the early work by Swingle and Webber and the later work by Swingle, Robinson, and Savage described by Traub and Robinson (6), the trifoliate orange was used as the principal source of cold resistance in crosses made for the production of cold-hardy varieties. These hybrids between various kinds of citrus and the trifoliate orange proved to be of outstanding cold hardiness, but their fruits were practically inedible. These results seem to have discouraged much further use of the trifoliate orange and its hybrids in the breeding of scion varieties of the disagreeable flavors they transmit to their progeny.

Swingle and Robinson (5) also used kumquats as sources of cold hardiness in crosses made with lemons and limes. From these crosses the limequats resulted; and several of these, the Eustis and Lakeland limequats in particular, have been widely used in dooryards as hardy substitutes for limes.

The current citrus-breeding work in Florida, Texas and California is being closely coordinated. The large and extremely valuable collection of citrus species, varieties and relatives at Orlando and the smaller but very useful ones at Weslaco and Indio are available for hybridization and selection work at all three stations. Also, materials from the extensive citrus collection of the University of California Citrus Experiment Station at Riverside are available for our use. Crosses that are wanted at one station are made wherever the materials are available but mostly at Orlando and Indio, and the seeds are sent to the places where the trees are to be grown and tested.

SOURCES OF COLD HARDINESS IN SCION VARIETIES

The most critical problem in breeding for cold-hardy scion varieties is that of finding satisfactory sources of cold hardiness. The trifoliate orange seems like the most promising source from which to make large improvements in the cold tolerance of citrus, but because it and its first-generation hybrids impart disagreeable flavors to their progeny, it is likely that many years of back-crossing and selection will be required to transfer to citrus varieties a high degree of cold tolerance and to eliminate from their inheritance the factors that produce the pungent and disagreeable flavoring compounds. While it seems highly desirable to pursue such a long-term program of transferring cold tolerance from the trifoliate orange to citrus in the hope of eventually obtaining varieties with good quality and much-improved cold tolerance, other less cold-hardy varieties are of more immediate promise for producing varieties suitable for commercial production.

Possibly the most promising immediate sources from which to introduce cold hardiness into mandarins, sweet oranges, tangors, and grapefruit are the satsuma oranges, the Changsha mandarin (possibly the hardiest of the tangerines) and to a lesser extent, the Dancy tangerine. In the freezes of November 17 and 18, 1958, at Indio several young Changsha trees were only slightly injured, whereas Willow Leaf and several other tangerine varieties of the same age and growing nearby were severely injured (Fig. 1, A and B). It also seems worth while to try to introduce into citrus from the kumquat factors that contribute to early and profound winter dormancy. For breed-

Continued on page 22

Seasonal Changes In Florida Tangelos

Continued from page 18

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Breeding Citrus For Cold Hardiness

Continued from page 20

ing acid fruits some sources of cold hardiness are the Meyer, Gul-Gul, and Kusner lemons, the kumquat, lemonquats and limequats, and possibly the citrangequats.

There is also considerable possibilities of reducing losses of the fruit itself by breeding and selection for earliness of ripening; that is, by producing varieties that so far as the fruit is concerned escape most of the severe freezes, which are likely to occur from late December to mid-February. Some of the varieties available for this work are the Clementine, Willow Leaf, and Honey tangerines; the Hamlin, Shamouti, Tarocco, Moro and the navel oranges; the Orlando and Pearl tangelos. The Salustiana, an early orange recently introduced to our collection from Spain, should soon come into flower and be available for breeding. This is an excellent, early, seedless, round

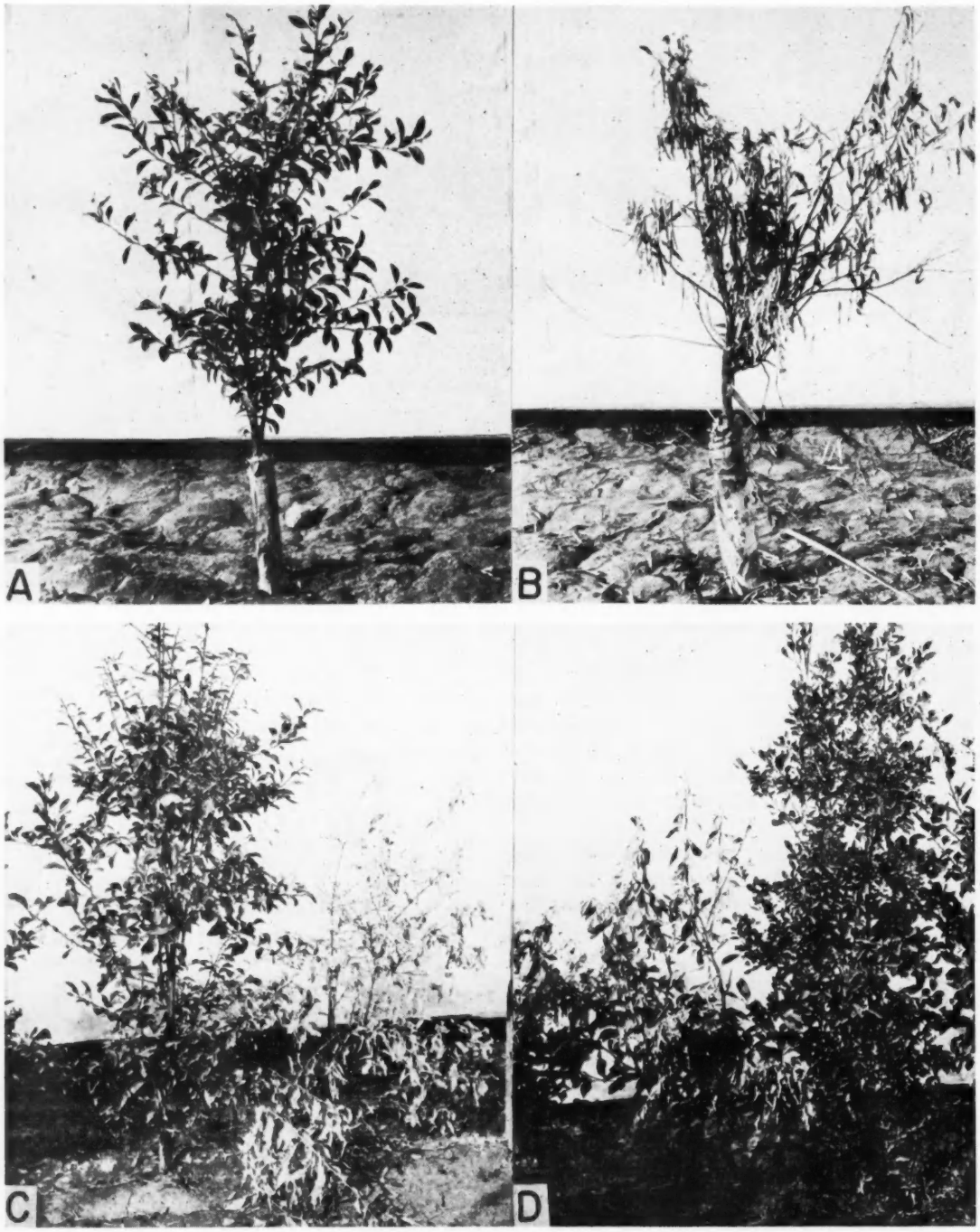

Fig. 1. Variation in cold injury of citrus varieties in freezes of November 17 and 18, 1958, at Indio, California. A—Changsha mandarin on Cleopatra rootstock. B—Willow Leaf mandarin on Troyer rootstock. Both planted 1 year and growing 20 feet apart. C—Calamondin x Eureka lemon hybrid seedlings, 3 years old; showing segregation for cold tolerance. D—Rangpur lime x Brazil sour orange hybrid seedlings, 3 years old; showing segregation for cold tolerance.

orange that, in Spain, ripens with the navel oranges.

SOURCES OF COLD HARDINESS IN ROOTSTOCK VARIETIES

In the breeding of cold-hardy citrus we are chiefly concerned with the scion variety because usually it is the dominant factor in determining the cold tolerance of a citrus tree, but the rootstocks may be of considerable importance, and under some conditions, as for example, in very light sands, highly calcareous or saline soils, it may have a profound influence on the cold tolerance of the tree.

We already have some very cold-hardy rootstocks; the sour orange, the trifoliate orange and its hybrids —the citranges, citrumelos, citrandarins, citrangequats, etc. They are, however, suited neither to all scion varieties nor to all soil conditions. We need to obtain rootstocks that combine cold hardiness with other desirable traits such as that of inducing in the scion vigorous growth and high yield or high quality of fruit, tolerance to highly calcareous or saline soils, and resistance to root rot. There are fairly large numbers of rootstock varieties with special qualities that should be hybridized with the most cold-hardy varieties and selected for testing as stocks. Among these Rangpur, Cleopatra and Sunki are salt tolerant; the shaddocks, Seminole tangelo, citrumelo 4475 and a Savage seedling are resistant to foot rot; Rough lemon, **Citrus macrophylla**, and Rangpur produce virorous growth and high yields on light soils; and Sour orange, Rough lemon and Shekwasha mandarin are tolerant of calcareous soils. We especially need to determine if any rootstock can be produced that will have an appreciable effect in inducing winter dormancy of the scion variety in areas where winter temperatures are relatively high for long periods. The kumquats possess the important faculty of remaining dormant through fairly long warm spells in winter. If this characteristic is heritable, perhaps it can be transferred to types more useful as stocks than the kumquat.

RELATION OF PHYSIOLOGY OF COLD HARDINESS TO BREEDING

The basic work on the physiology of cold hardiness in citrus and most of the testing for hardiness of varieties and hybrid progenies produced in the breeding work will be done at the Weslaco laboratory, where specific facilities are available. It is expected that information obtained in the work on the physiology of cold hardiness in citrus will be of great value in breeding for cold hardiness.

In fact, for most effective breeding work it is essential that we know more than we now do about the nature of cold hardiness in citrus and the citrus relatives. The breeder must know what hereditary characteristics to look for and how to make tests of seedling progenies so that reliable selections of cold-tolerant individuals can be made. It is obvious that one of the factors involved in the cold tolerance of citrus is dormancy of the tree—a condition in which little or no cell division and growth occur. We need to know more about the conditions required to induce or maintain dormancy in different species and varieties. Another possible heritable factor that citrus or some

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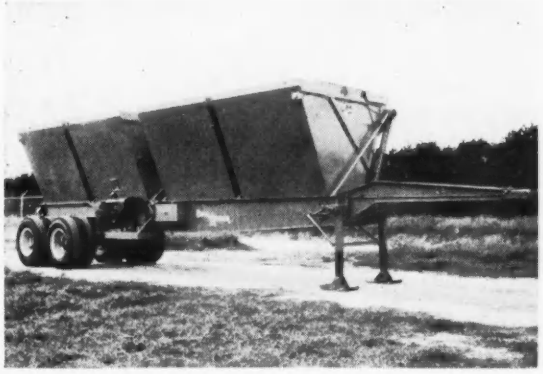

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When it comes to too much rain Nature has just about got control of the situation. 'Course when it's too dry we can irrigate. But aside from all ailments originatin' with the weather our most important production function is to see that our crops is properly fertilized and cultivated, 'n pests is controlled to the greatest degree possible.

As a matter of fact, all jokin' to one side, if'n all of us folks who is in business was able to operate so they wasn't no problems connected with the things we do, we'd find that eventually we'd git so content with everything runnin' smooth, that when it did git to be rough goin' we jist wouldn't know what to do. So as long as it don't stay rough all the time maybe it keeps us on our metal a bit better to have some problems now and then.

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Breeding Citrus For Cold Hardiness

Continued from page 23

hybrids of citrus and the trifoliate orange may possess is the ability to undergo cold hardening—the process that enables some plants, for example, cabbage and wheat, after being subjected to near-freezing temperatures for a few days to withstand for some days afterwards relatively severe freezing without injury. Possibly there are other heritable factors involved in cold tolerance of citrus that should be taken into consideration. Clear definition of these factors and the development of reliable and satisfactory test methods will no doubt call for physiological investigations under carefully controlled conditions such as may be obtained at the cold-hardiness laboratory at Weslaco.

The breeding work in California is carried on at two stations. The crosses are made at Indio, where the variety collections are maintained, but most of the seedling progenies are grown at the Southwestern Irrigation Field Station at Brawley.

Much of the work related to cold hardiness has been done with rather broad objectives in view. An especial effort has been made during the last few years to collect cold-hardy varieties for use in breeding both scion and rootstock varieties. A large collection has been made of trifoliate orange strains and hybrids and the available kumquats and kumquat hybrids. We have been interested in collecting, selecting and testing salt-tolerant materials for use in breeding for salt tolerance in rootstocks. Results of the extensive investigations on salt tolerance of citrus rootstocks conducted during the last 10 years in Texas by Cooper and his associates (2, 3, 4) have provided us with a sound basis for breeding for salt tolerance in rootstocks. That work also showed that the degree of salt tolerance has a profound influence on the cold hardiness of citrus trees growing on highly saline soils (1).

In most of the hybridization work so far accomplished the objective was usually the combination of several desirable characteristics in the hybrid progenies. In some of these cold hardiness was a major consideration, but in many it was secondary. An account of the hybridization work on scion varieties related to cold hardiness follows:

Lemons and Limes

In the interior desert areas of Arizona and California, where summers are hot and winters are cold, the Meyer lemon has been found to be cold hardy and highly productive. With the objective of combining the hardiness of the Meyer and the high fruit quality of the commercial types, crosses were made in 1952 between the Meyer and the variety Messina, 2 strains of Eureka, and 2 strains of Lisbon. Over 700 seedlings were produced, and many of these have fruited. The Messina, Eureka and Lisbon were the seed parents, and as they produce many nucellar seedlings, it was difficult to determine whether some of the desirable seedlings are hybrid, but a few that apparently are show promise. Further study will be necessary to select the best of these. It will also be necessary to test them for cold tolerance.

With the object of producing a small hardy acid fruit of the lime type suitable for use as a dooryard fruit in cold locations, the Calamondin lime was crossed with Eureka and Lisbon lemons and with the Rangpur lime. Only a few hybrids were produced from each cross and these are not yet in bearing. In the 1958 freezes the Calamondin x lemon hybrids showed striking segregation for cold tolerance (Fig. 1, C).

Loose-skin Types.

Extensive hybridization of tangerine, tangor, and tangelo varieties was accomplished in the period 1952 through 1954. The seed parents most extensively used, Clementine, King, Wilking, Honey, Umatilla and Temple, were selected because they produce a high proportion of hybrid seedlings. Among the pollen parents were Dancy, Kinnow, Honey, Kara, Wilking, and Willow Leaf tangerines; Orlando, Minneola, San Jacinto, and Pearl tangelos; Umatilla and Temple tangors. These crosses were not made specifically to produce cold-hardy varieties, but in the several thousand seedlings produced it is apparent that wide variation in hardiness exists; and cold hardiness is one of the factors that will be considered in the testing and selection of seedlings for commercial trial. Many of these seedlings have fruited and about 50 have been propagated on a common rootstock for further observation at Indio. Budwood of many of them has been sent to Weslaco for observation and testing for cold hardiness.

Breeding Early Tangerines and

Continued on page 30

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Cold Hardiness In Citrus As Related To Dormancy

Continued from page 10

te grow and the cambium was highly active in all parts of the trees and the trees were injured at 27°F. Thus, these trees lost their cold hardiness. These results clearly indicate that drought will induce dormancy and cold hardiness in grapefruit and Meyer lemon.

Effect of Plant Regulators On Dormany and Cold Hardiness

Growth and dormancy was controlled in chrysanthemums by Cathey (2) by means of foliage sprays of various plant regulators. In these experiments he induced growth at will by the use of gibberellic acid and could stop it by an application of Amo-1618, a quaternary ammonium compound. Experiments on citrus (6) show that gibberellic acid sprayed on trees on December 12 induced new growth within 2 weeks, but Amo-1618 used over a wide range in concentration from 1 to 1000 p.p.m. had no apparent effect on growth. The unsprayed (control) trees had 3 degrees of cold hardiness during early January as compared with no cold hardiness in the gibberellic-acid-sprayed trees. Thus the use of gibberellic acid sprays on citrus trees during winter is a definite cold hazard. This lack of cold hardiness of the gibberellic-acid-sprayed trees was not affected by spraying them with Amo-1618 at various times during the winter. Thus both the visual observations of effects on dormancy and the cold-hardiness tests with the portable freezer show the failure of Amo-1618 to induce dormancy of citrus trees.

For control of dormancy and cold hardiness in citrus both a growth promoter and a growth inhibitor are needed. A large number of plant growth regulators besides the two just named have been tested on citrus (7). These compounds were applied as foliage sprays in concentrations of 1 to 1000 p.p.m. and as soil drenches at concentrations of 25 to 250 p.p.m. In these experiments 2,4-D had no appreciable effect on cambial activity and cold hardiness, but it had formative and toxic effects. Maleic hydrazide and 2,4,5-T treatment resulted in a slight inhibition of cambial activity, pronounced bud inhibition and 1 degree of cold hardiness, but severe injury resulted from concentrations effective enough to inhibit growth. From these experiments the control of cambial activity and bud growth with plant regulators used does not appear promising. In contrast, Stewart (15) obtained effective bud inhibition from maleic hydrazide treatment of cold-injured citrus trees in Florida. In this instance the sprays were applied to dormant, defoliated trees and the treatment inhibited bud growth, while in the experiments described herein the maleic hydrazide was applied to normal trees with a full compliment of leaves prior to a freeze treatment. In view of Stewart's results, the use of maleic hydrazide in inhibiting bud growth merits further trial.

Summary

The results summarized show that approximately 6 degrees of cold hardiness can be attained in non-dormant trees by the induction of complete dormancy and lesser amounts under semi-dormant conditions. The degree of cold hardiness of trees growing under natural conditions in the field in the Rio Grande Valley of Texas was determined by the use of a portable tree freezer.

The search thus far for an effective chemical growth inhibitor or dormancy inducer has been unfruitful. Trials with 2,4-D, 2,4,5-T, Amo-1618, growth regulators were more or less ineffective.

The control of dormancy involves controlled growth promotion as well as controlled growth inhibition. Growth was easily promoted at will even in the winter dormant period by the use of gibberellic acid.

Withholding irrigation water in the winter can induce dormancy and increase cold hardiness. The procedure, however, may be hazardous as citrus orchards in Texas have at times been severely injured by drought. Also, drought may possibly be broken by an untimely rain which might result in more vigorous bud growth and less cold hardiness than in trees that had been irrigated regularly.

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Continued on page 34

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Weather Improves Fla. Citrus Quality

Dry, cool weather in the citrus belt is continually improving quality of Florida citrus, Robert W. Rutledge, Florida Citrus Mutual general manager, said in a current crop condition and outlook report released today.

He said although most groves are generally in good condition there is still some "above normal" dropping and splitting of fruit in some areas due to excessive rain during the growing season.

The 14-county report, compiled after a survey of crop conditions by Mutual's field representatives, is "a representative sampling and not all inclusive," Rutledge said.

Excerpts from the report by counties:

POLK AND HILLSBOROUGH — Acids are holding well and solids continue to climb. Splitting and dropping has about ceased but it is generally felt that the loss was severe enough to effect materially the volume of Valencias to be harvested. Many crops which have usually gone into frozen orange concentrate have already been utilized in single strength this season.

LAKE — Harvesting continues in fair volume on early and mid-season oranges, tangerines, tangelos and grapefruit. Due to extreme wet growing conditions during the summer this crop is low in both acids and solids. Recent cold weather did no damage except to some tender growth that was burned.

SEMINOLE, ORANGE AND OSCEOLA — Solids have generally increased during the last two weeks and acids have remained fairly steady although an acid drop is noted on fruit having a substantial increase in solids. No damage reported from recent cold weather except to some tender growth.

DESOTO — Tree condition remains good in this area generally. An above normal dropping of fruit on mid-season oranges and grapefruit. Growers have finished their cultivation in this area.

HARDEE — Groves are in excellent condition. Most early oranges will be moved in another week or ten days and it is expected that mid-season oranges will move steadily through December and January.

LEE, HENDRY AND CHARLOTTE — Although groves are generally in good condition in this area there is quite a bit of water damage apparent. Because of rather heavy droppage some growers are moving their mid-season fruit now.

MARION — Practically all low acid fruit has been moved from this area and buying activity is slow at the present. Pests are generally under control although there is some spraying and dusting for mite control.

VOLUSIA AND PUTNAM—Splits and drops are not so bad here with the exception of seedling oranges which are showing an above normal loss of fruit. There is still excessive water in some areas. Fruit sizes are not as large as anticipated while Duncan grapefruit are oversized.

KEEP INFORMED — READ THE CITRUS INDUSTRY

1960 Florida Citrus Exposition In Winter Haven Jan. 16-23

Continued from page 7

mittee of the Exposition, will have special trains to bring the group from Miami and to return them the following day.

The NCA will have only three scheduled functions. These include the Canner's Day and Agricultural Day luncheons and the Fruitmen's Dinner.

Exposition officials say this will be one tour in which the group can select its own places to visit and its own time schedule.

One of the unusual attractions at the Exposition, along with many outstanding citrus displays, will be an exact replica of the U. S. Moon Rocket. This authentically reproduced rocket has been constructed with two over-sized citrus cans forming the space chamber and booster. Giant sized citrus fruit form the fuel tanks of this three-stage, space-age rocket, which will be prominently spotlighted in the newly christened Citrus Plaza.

In extending an invitation to everyone to attend the 1960 Florida Citrus Exposition, President Ben Hill Griffin, Jr., stated "We would like for everyone to come and see for themselves the tremendous strides which have been made in the past few decades as modern, improved production methods launch the fabulous Florida citrus industry into the space age."

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Florida Citrus Industry Buys Land To Aid USDA Research

Florida citrus growers and industry leaders have purchased 500 acres of land for the use of U. S. Department of Agriculture scientists in developing and improving citrus stock. Work at the new site will supplement field research currently carried on by USDA's Agricultural Research Service at the U. S. Horticultural Station at Orlando.

The industry formed the Florida Citrus Research Foundation for the purpose of buying the land and aiding citrus production research. The Foundation is now conducting a drive to collect money for the full purchase price and an additional $50,000 to improve the land. The land, located near Leesburg, Fla., was purchased at a cost of $150,000 and will be leased rent-free to the Agricultural Research Service for 99 years.

Some of the research to be conducted will include breeding new varieties in an attempt to produce (1) early maturing and extra-late maturing oranges and grapefruit to extend the processing and fresh fruit marketing period, (2) "kid-glove" type oranges of good eating quality and good shipping qualities for a wide season of use in fresh fruit channels, and (3) varieties that produce more and better juice color and more sugar per acre.

The scientists will also attempt to produce both rootstocks and scion varieties that will be more resistant to cold and still produce high quality fruit on Florida's wide variety of soils. They will also continue to maintain the collection of over 600 citrus varieties and species, largest of its kind in the world. Material from the collection is used for breeding, rootstock, and selection.

The Florida citrus industry returns nearly a third of a billion dollars annually to growers.

CITRUS WAS STATE'S LEADING FARM CASH COMMODITY IN 1958

Cash receipts from all Florida farm marketings in 1958 totalled $689 million, according to a report by Zach Savage, agricultural economist with the Florida Agricultural Experiment Station.

This was an increase of 4 percent over 1957 figures. Of this $689 million, oranges, grapefruit and tangerines accounted for $265 million.

Citrus receipts were five times more than receipts from field crops and more than five times the combined income from greenhouse, nursery and forest products, and other fruits and nuts.

Savage says orange, grapefruit and tangerine receipts were $138 million more than income from vegetables, with potatoes, sweet corn and watermelons included.

Florida's 1958 citrus income was an increase of 15 percent over 1957. This state accounted for 66 percent of the nation's oranges and tangerines and 74 percent of the grapefruit grown in this country.

During my 89 years I have witnessed a whole succession of technological revolutions. But none of them has done away with the need for character in the individual or the ability to think. —Bernard Baruch.

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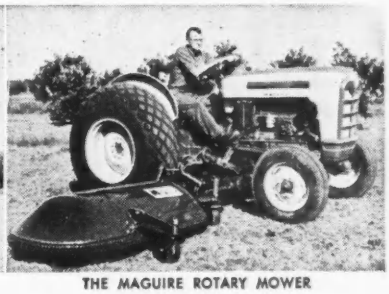
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Breeding Citrus For Cold Hardiness

Continued from page 26

Oranges to Escape Early Frosts

With the primary object of obtaining early tangerines, tangors and oranges of high quality a series of crosses was begun in 1953 and additional ones were made each year to the present time. If, as is expected, very early ripening fruits are obtained from some of these crosses, the fruit itself should escape injury in all except the very early frosts, which usually are not severe.

Seed produced from a cross of Clementine by Owari satsuma made at Orlando by Philip Reece were received in 1953. Of the 224 seedlings produced from these seed a few trees fruited at Brawley in 1958, and these indicate that this cross is likely to be a profitable one. Over 200 seedlings from a cross of Clementine by Hamilin were planted in 1954 at Brawley. Some of these fruited in 1958; several were quite early ripening, but the only one selected for second test was not as early as Clementine. Most of these seedlings have not yet come into bearing. An attempt was made in 1954 to obtain hybrids between several strains of navel orange as seed parents and Clementine and Honey tangerines, with the object of securing early seedless tangors of high quality. From large numbers of flowers pollinated a few seed were obtained and these produced only 2 or possibly 3 hybrids, and these have not yet fruited. These results suggest, however, that with sufficiently large scale pollinations of navel oranges it may be possible to obtain in a few years' time fairly large numbers of navel orange hybrids.

The Shamouti orange is not a commercial variety in this country, but in Israel it is considered to be one of the world's finest varieties. For several years we have pollinated large numbers of Shamouti flowers with Hamlin, Tarocco and Joppa pollen, in the hope of obtaining an early high-quality and nearly seedless orange. Though the yield of seeds has been small and the number of hybrids very few, it has been encouraging to obtain even a few hybrids. We hope to improve the conditions under which these crosses are made so as to obtain a higher yield of seeds. Temple orange produces some early-ripening seedlings, and as it produces only hybrids, it also has been used as seed parent in crosses with Hamlin, Tarocco and Shamouti oranges. In all of these crosses many of the hybrid seedlings are weak and worthless, so that rogueing is necessary.

Combining Cold Hardiness and Salt Tolerance in Rootstock Types

Since 1954 extensive hybridization work with rootstock varieties has been performed with the object of producing a series of rootstock types that combine various desirable traits. Especial attention has been given the trifoliate orange and its hybrids because many of them are resistant to root rot, induce in the scion variety the production of high-quality fruits, and under some conditions improve the cold tolerance of the scion variety. Because of the prevalence of saline water in many of the irrigated citrus districts the production of salt-tolerent rootstocks has been a major consideration in the hybridization work at Indio.

With the object of combining the factors for cold hardiness and salt tolerance in citrus rootstock types, crosses were made using as seed parents the salt-tolerant varieties Rangpur lime, Cleopatra and Sunki mandarins and as pollen parents several strains of the trifoliate

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orange, Troyer, Savage and Carrizo citranges, and the Brazil sour orange. Some of the hybrid seedlings, for example the Rangpur x Brazil sour orange hybrids, showed clear segregation for cold tolerance in the 1958 freeze (Fig. 1, 1, D). Several hundred of these hybrids are now under test in salt plots. Apparently, the factors responsible for salt tolerance are heritable because the progenies of several crosses have shown striking segregation for tolerance to high salts. Eremocitrus glauca is hardy and highly salt-tolerant but a slow, weak grower. Some of its hybrids, however, are vigorous and salt-tolerant and are being selected and tested for salt tolerence. The best of these will be used for hybridization with other species and varieties with the object of producing a cold-hardy and exceptionally salt-torerant rootstock variety.

Combining Cold Hardiness With Resistance to Root Rot and Other Qualities

In a search for plants highly resistant to injury from Phytophthora parasitica, the cheif cause of root rot or foot rot of citrus in the warm soils of the desert citrus areas, seedlings of a large number of trifoliate orange varieties and hybrids, sour orange varieties, and mandarin and tangelo varieties have been screened for resistance to P. parasitica. This work has been carried out during the past 3 years by John B. Carpenter, citrus pathologist at Indio. A method that results in infection of all of the seedlings was devised. Following infection most of the seedlings die and only the highly resistant ones quickly recover and resume growth. Large numbers of resistant seedlings are now under field test. Some years will be required to complete the screening of these for cold hardiness and other qualities desirable in a rootstock.

Crosses have been made between trifoliate orange varieties and the following: Suen Kat, Cleopatra, Sunki and Shekwasha mandarins, Sunshine tangelo, several shaddocks, Iran lemon and Rough lemon, and several sweet orange varieties with the object of combining the factors in the trifoliate orange that induce high quality of fruit and cold hardiness with various qualities carried by the other parent, such as the tendency to induce high yields, vigor of growth, disease resistance, or tolerance to high-lime soils.

Most of these crosses have been made so recently that few of the seedlings have fruited. Unless the seedlings of a variety are largely nucellar, it is of limited value as a rootstock even though it has otherwise excellent qualities. Until the seedlings produced by these crosses are examined for nucellar embryony and tested in other respects, no prediction of their value can be made.

The detailed method of handling the testing of seedlings produced at Orlando and Indio in the breeding of scion varieties and rootstock varieties is yet to be worked out, but present plans are to send much of this material as seed or as budwood to Weslaco for tests of salt tolerance in the field or for tests of cold hardiness in the controlled-temperature rooms and greenhouses there.

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Continued on page 33

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SPECIAL AGRICULTURAL EVENTS

From the minute the gates swing open Tuesday, February 2, each day of the 1960 Florida State Fair will be packed with events of special interest to farmers, growers, livestock raiser, dairymen and nurserymen. State and County Exhibits . . . Dairy and Beef Cattle Shows and Sales . . . Certified Meat Hog Contest . . . Table Beef Contest . . . Barrow, Poultry, Swine and Rabbit Shows . . . Fat Stock Show and Sale . . . Parades of Beef and Swine Champions . . . FFA Activities . . . 4-H Club Events . . . Horticultural Exhibits . . . International Orchid Show. Don't miss any of the fascinating features of the 1960 Florida State Fair — Great Show Window of the Sunshine State!

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Indian River Fruit Seminar

January 13-14, 1960, At Fort Pierce

Following is the program of the Indian River Seminar to be held at Ft. Pierce, Jan. 13-14.

Jan. 13, 1960, 9:30 a. m.

Presiding — F. S. Perry, District Agent, Agricultural Extension Service

Invocation — Albert Morris, Rector, St. Andrews Episcopal Church, Fort Pierce

Opening Remarks — F. S. Perry

The 1960 Spray and Dust Schedule (Better Fruit Program) — James E. Brogdon

Current Status of Greasy Spot in the Indian River Area — Dr. Mortimer Cohen

Recess

Trends in the Califronia Citrus Industry — R. G. Platt, Extension Subtropical Horticulturist, University of California

Current Status of Brown Rot in the Indian River Area — Dr. Mortimer Cohen

Lunch

Reconvene at 1:30 p. m.

Presiding — Charles D. Kime, St. Lucie County Agricultural Agent

Does Fresh Fruit Have a Profitable Future? — Dr. William Grierson

Pruning and Hedging — Dr. Al Krezdron

A Quick Look at Some of the Newer Varieties — Jack T. McCown

Recess

Citrus Growers Income Taxes — a Discussion — Laurie Tomlinson, District Director, Internal Revenue Service, and W. O. Daley, C.P.A.

January 14, 1960, 9:30 A. M.

Presiding — James T. Oxford, Brevard County Agricultural Agent

Opening Remarks — James T. Oxford

Citrus Expansion in the Indian River Area Through Co-operation with the Central and South Florida Flood Control District — Brian McCarty, Chairman, Central and South Florida Flood Control District.

Water Damage to Indian River Citrus in 1959 — Dr. R. R. Hunziker

Drainage Control System in Citrus Groves — Dr. R. R. Hunziker

Recess

Fruit-Setting Hormones — Dr. Al Krezdorn

Induce Dormancy in Citrus — Maleic Hydraside — William M. Mathews

Chemical Weed Control — Dr. Dale Kretchman

Lunch

Reconvene at 1:30 p. m.

Presiding — Forrest T. McCullars, Indian River County Agricultural Agent

The Moroccan Citrus Industry — Dr. J. F. L. Childs

Citrus Rootstocks for the Indian River Area — Dr. Frank Gardner

Recent Developments in the Florida Budwood Program — Gerald Norman

Fertilizing for Fruit Quality — Dr. Herman Reitz

PRETTY GIRLS TO TAKE PART IN NATIONAL CANNERS CONVENTION

A bevy of 10 beauties—including five to be chosen from among the 1960 Florida Citrus Queen contestants—will be the Florida Citrus Commission's emissaries to the National Canners Convention in Miami Beach January 16-17.

Known as the Sunshine Orange Girls, the group will form a radical change from Miami Beach's concentional bathing beauty method of greeting guests.

The girls will be on hand at Miami's International Airport dressed in old-fashioned gowns dispensing Florida orange juice to the hundreds of delegates from all over the nation who will attend the National Canners Convention from January 16 to 20.

The girls will dispense orange juice for the Citrus Commission at the airport on Saturday, January 16. The next day the Florida Citrus Commission will set up the orange juice dispensing machines at the Americana Hotel in Miami Beach.

The Americana will be the headquarters for the convention group during the four-day session.

Five of the 10 girls will be selected from among Cypress Gardens aqua-maids. The other five will be named from among those girls who enter the Florida Citrus Exposition Queen Contest.

The girls will leave Miami Beach in time to return to Winter Haven for the three-day queen competition which begins on January 18th.

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Breeding Citrus For Cold Hardiness

Continued from page 31

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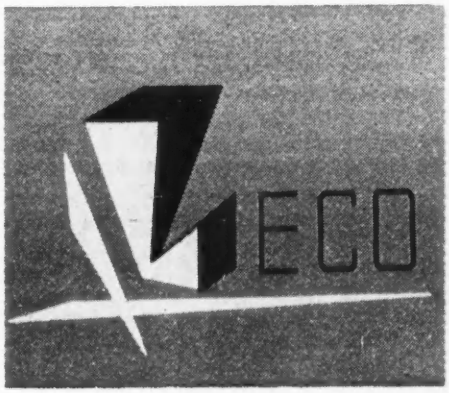

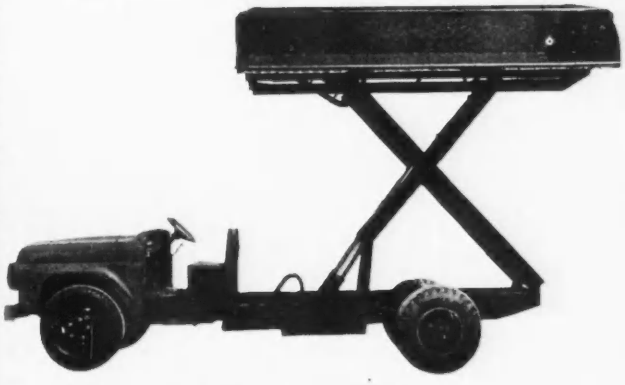

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Cold Hardiness In Citrus As Related To Dormancy

Continued from page 27

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